ITEA Journal 2009; 30: 381–385

Chemical and Biological Defense Test and Evaluation—A Hallmark of Integrating DT and OT

Charlie Holman, Ph.D.
U.S. Army Test and Evaluation Command, Alexandria, Virginia
Robert L. Berkowitz
VRC Corporation, Alexandria, Virginia

The most operationally realistic testing of chemical and biological defense systems uses actual biological and chemical warfare agent; however, testing live or actual agents is restricted to laboratory containment chambers, which are operationally unrealistic environments. This state of affairs has driven the chemical and biological defense community to integrate developmental testing (DT) and operational testing (OT) to support the evaluation process. Three paradigms are commonly used to integrate chemical and biological defense DT and OT. They are (a) conducting DT with systems before and after OT, (b) developing agent simulant relationships in DT, which are then applied to OT data, and (c) modeling and simulation. This article supplies chemical and biological defense system examples for each paradigm.

Key words: Biological agent detection; chemical agent detection; developmental testing; integrated testing; modeling and simulation; operational testing; public safety; realistic testing.

The most operationally realistic testing of chemical and biological defense systems will use actual biological and chemical warfare agent. As a result of public law, treaty, and concern for public safety, testing with actual agent is restricted to laboratory containment chambers, which is the least operationally realistic environment. As a result, the chemical and biological defense test and evaluation (T&E) community has been forced to develop and use paradigms that combine operational testing and developmental testing. The operational test (OT) part brings the realism of actual warfighters executing missions in combat-like environments. The developmental test (DT) part brings the realism of actual biological or chemical agent. These paradigms are the following:

- conducting DT with systems before and after OT,
- developing agent simulant relationships, and
- modeling and simulation.

A simulant is a relatively harmless substance that has some of the properties of agents and can be released into the environment. These three basic paradigms are not mutually exclusive and may be used in combination on the same system under test.

This article describes how these three basic paradigms to integrate DT and OT have been used as the lynch pins for evaluation of chemical and biological defense systems.

Paradigm 1: DT with systems before and after OT

During OT, systems are used by warfighters while executing wartime missions. Use, care, and maintenance of the system under test are typical of what could be expected during actual operations. OT, like wartime, tends to be a strenuous environment. During OT, system performance is often degraded. The total effect of an OT on the performance of system under test can be determined by conducting DT performance testing on those systems both before and after the OT. The effect of less use than is measured by a whole OT on the performance of a system under test can be measured by periodically removing systems from OT for DT performance testing. This paradigm has been routinely used on protective garments since the Joint Service Lightweight Integrated Suit Technology (JSLIST) testing

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
SEP 2009		**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Chemical and Biological Defense Test and Evaluation-A Hallmark of Integrating DT and OT	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Army Test and Evaluation Command,4501 Ford Ave,Alexandria,VA,22302-1458**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Figure 1. Beach assault from Joint Service Lightweight Integrated Suit Technology operational testing.

in the early 1990s. It was also applied to the Joint Biological Point Detection System (JBPDS) as well as other detectors.

During OT, the JSLIST candidate protective garments were worn by U.S. Marines, soldiers, airmen, and sailors while conducting combat missions. These missions included offensive and defensive actions at 29 Palms Marine Corps Base, a beach assault at Camp Pendleton *(Figure 1)*, shipboard operations, and flight line operations. The missions were intended to put the same wear, stresses, and strains on JSLIST as would occur during combat. The garments were worn for up to 60 days. They were worn 23 hours a day. Warfighters not only conducted missions in JSLIST but also slept and ate in this protective garment. The suit was laundered every other week. A random sample of JSLIST protective garments and the base line protective garment were removed from the OT after 15, 30, 45, and 60 days of wear and sent to DT performance testing. It was known that mission types were not equivalent. Offensive actions result in more wear on garments than defensive operations. Hence, care was taken to randomly choose garments and to spread mission types somewhat uniformly over the 60 days of OT.

The DT performance testing include various types of swatch testing with various chemical warfare agents, and whole system testing in which warfighters wore JSLIST in a simulant chamber performing a prescribed task list. In addition to the garments with 15, 30, 45, and 60 days of wear, new garments were also tested in DT performance testing.

The JSLIST evaluation compared the effect of mission wear time on the performance degradation of JSLIST candidates to the baseline. The fielded protective garment served as the baseline. This strategy of performing DT both before and after OT resulted in identifying the JSLIST candidate garment that best increased the amount of protection (Musgrave et al. 1997).

The JBPDS was tested in accordance with this paradigm in the Ambient Breeze Tunnel (ABT) before and after OT I. The ABT is a DT wind tunnel in which simulant concentration can be accurately controlled and measured. This testing revealed that after OT there was significant and substantial degradation in detection performance. The degradation in performance was traced to a LASER in the detection system. The LASER design was upgraded. Subsequent testing demonstrated that the new LASER did not degrade during OT (Chipman et al. 2001).

This paradigm combines or integrates DT and OT results to produce a powerful evaluation tool to ascertain if system performance is degraded during OT.

Paradigm 2: Agent-simulant relationships

A simulant is a relatively harmless substance that possesses, for the attributes being measured or tested, properties similar to agents of interest and that may be

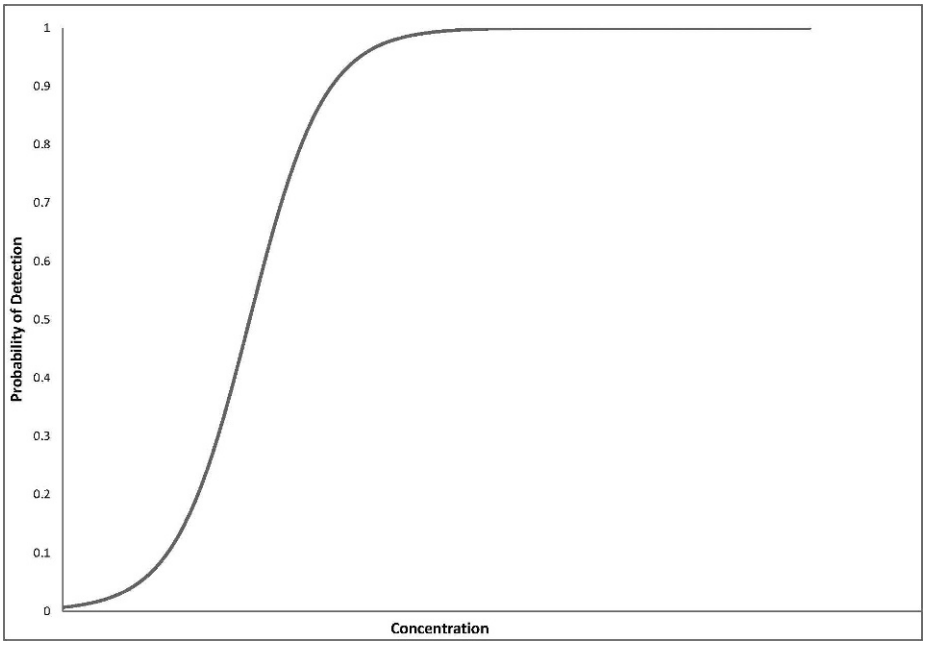

Figure 2. S-shaped or sigmoid curve depicting the relationship between agent detection and agent concentration.

released into the environment since the simulant is not dangerous. Much effort is invested in simulant selection and development. For testing detectors, it is desirable that the system under test "sees" the simulant the same way as it "sees" the agent that the simulant is simulating. Other properties of interest include similarities in dissemination and cloud dynamics. No simulant is an exact match in all properties of interest to the agent.

Traditional biological detection simulants include ovalbumin for toxins, the bacteriophage Male Stereotype 2 (MS2) for viral biological warfare agents, *Erwinia herbicola* for vegetative biological warfare agents, and *Bacillus subtilis* for spore-forming biological warfare agents. Chemical simulants are much more numerous than biological simulants; two commonly used simulants for chemical detectors are triethyl phosphate for nerve agent and acetic acid for blister agent.

The Biological Integrated Detection System (BIDS) and BIDS Pre-Planned Product Improvement (P3I) were tested in the early to mid 1990s. They used both biological warfare agent and the traditional biological detection simulants in DT laboratory containment chamber testing and traditional biological detection simulants in OT. Inferences focused on laboratory results with agent and OT results with simulant. It was noted in DT that the detection performance of BIDS for a group of agents lay between the values of two of the stimulants. This finding enabled us to predict that the field performance of BIDS against these agents would be bounded by the OT performance against these two simulants.

For both biological warfare agent detectors and chemical warfare agent detectors, the variable that has the most profound effect on detection performance is agent concentration. As concentration increases, detection performance tends to increase. At some high level of agent concentration, all releases are detected. As concentration decreases, detection performance tends to decrease. At some low level of agent concentration, no releases are detected. The plot formed by agent-concentration and detector-performance is s-shaped or sigmoid as is depicted in *Figure 2*. Logistic regression is a statistical framework based on a sigmoid relationship. Logistic regression has been useful in modeling detection performance and in developing the agent-simulant relationships in both the JBPDS and the Joint Chemical Agent Detector.

Three of the traditional biological detection simulants—ovalbumin, MS2, and *Erwinia herbicola*—have been considered inadequate representations of actual biological warfare agent (Fitch et al. 2004). In an effort to obtain simulants that better represent biological warfare agents of interest, closely related organisms or vaccine strains were used for viruses and bacteria. Toxoids were used for toxin. A toxoid is a toxin that has been denatured or broken into nonhazardous components. The toxoids, closely related organisms, and vaccine strains are referred to as agent-like organisms (ALO). To eliminate any chance of infection from the closely related organisms or vaccine strains, these were killed with ionizing radiation.

The DT portion of the Whole System Live Agent Test of JBPDS was conducted to test JBPDS detection performance when challenged with biological warfare agent and ALOs. Both live and killed agent and ALO were used. JBPDS performance testing was conducted with both living and killed ALOs, and living and killed agents, in laboratory containment chambers. JBPDS performance testing was conducted with only killed ALO simulants in the ABT and field. The end results of this DT testing were twofold:

1. JBPDS detection performance when challenged with live agent in a laboratory containment chamber was characterized.
2. Relationships were developed to relate JBPDS detection performance when challenged with killed ALO simulants to JBPDS detection performance when challenged with live agent.

The JBPDS OT used the new killed ALO simulants. The relationships developed in DT between JBPDS detection performance with killed ALO simulants and live agent were used to predict JBPDS performance as if it had been challenged with live agent (Holman et al. 2008).

The evaluation of JBPDS provided predictions of JBPDS performance against live agent based upon OT challenges with killed ALO simulants and relationships developed in DT.

Paradigm 2, the development agent-simulant relationships, combines or integrates relationships developed in DT with OT results to support an integrated evaluation of how the system performs against agent.

Paradigm 3: Modeling and simulation

The keystone in both the Joint Service Lightweight Standoff Chemical Agent Detector (JSLSCAD) and the Joint Biological Standoff Detection System (JBSDS) evaluations was the use of modeling and simulation to integrate DT and OT results to predict system detection performance.

JSLSCAD modeling and simulation was conducted by a team that included Johns Hopkins University Applied Physics Laboratory (JHU APL), the Joint Project Manager for Contamination Avoidance, and both Dugway Proving Ground and the U.S. Army Evaluation Center from the Army Test and Evaluation Command. The backbone of the JSLSCAD model was a model developed by Honeywell, which was used to support JSLSCAD development. Spectral backgrounds, meteorological data, and other data were collected by JHU APL in various locations of tactical interest and used in the JSLSCAD model. The vapor, liquid, and solid tracking transport and dispersion model, with chemical and biological analyzer, was used to provide cloud size, concentration, and cloud propagation information for chemical warfare agents. A scanning model was used to allow the JSLSCAD model to have multiple chances of detecting a chemical cloud as it moved downwind. OT and DT field tests and laboratory tests provided a base for validation, verification, and accreditation of the modeling and simulation.

The modeling and simulation results were the best source of information on the detection performance of JSLSCAD. The modeling and simulation provided a means to integrate DT and OT in an evaluation that provided information on the effectiveness in detecting chemical warfare agents in a threat realistic environment. Model results can be found in Holman et al. (2007).

The JBSDS modeling and simulation was conducted by a team that included JHU APL, the Joint Project Manager for Biological Defense, Air Force Operational Test and Evaluation Center, and the Army Test and Evaluation Command. The model was based on the capability of the system to re-analyze "playback" data from previous trials. Some of the parameters in the system "playback" are then changed from parameters that are indicative of simulant to parameters that are indicative of biological warfare agent. The basic playback uses field DT or OT data. The agent unique parameters are measured in a laboratory during a DT event.

These modeled results are the best source of performance data to evaluate the detection performance of JBSDS. The modeling and simulation provided a means to integrate DT and OT in an evaluation that provided information on the effectiveness in detecting and discriminating biological warfare agents in a threat realistic environment. This process is described in Shirakawa, Russell, and Holman (2008) and Przybylowicz et al. (2003).

Paradigm 3 modeling and simulation provides an opportunity and means to integrate DT and OT results to support an integrated evaluation of how a system performs when challenged with agent.

Conclusion

Biological and chemical warfare agents cannot be released into the environment during OT, and they can only be tested in DT laboratory containment chambers. Hence, the only way to obtain chemical and biological defense system operational relevant evaluations is to integrate DT and OT. ❑

CHARLIE E. HOLMAN is chief of the Chemical and Biological Defense Evaluation Division at the U.S. Army Test and Evaluation Command in Alexandria, Virginia. He has 19 years of experience in evaluating chemical and

biological defense systems. He received a bachelor of science degree in biology from the Pennsylvania State University, University Park, Pennsylvania; a master of science degree in biology from Bloomsburg State University, Bloomsburg, Pennsylvania; a master of mathematics degree from the University of South Carolina, Columbia; and a doctor of philosophy degree in biodefense from George Mason University, Fairfax, Virginia. E-mail: charlie.e.holman@us.army.mil

ROBERT L. BERKOWITZ is currently a senior analyst with the VRC Corporation in Alexandria, Virginia, supporting the Chemical and Biological Defense Evaluation Division at the Army Test and Evaluation Command. He received his bachelor of arts degree in mathematics from Temple University in Philadelphia, Pennsylvania, in 1968, and his master of arts degree, also in mathematics, in 1972 from the University of Maryland, College Park. He has supported many different government agencies including the U.S. Army, Navy, and Federal Aviation Administration. E-mail: robert.berkowitz@us.army.mil

References

Chipman, M., C. E. Holman, K. Finanger, J. Fuller, R. Jernigan, L. Wollenberg, B. Rodriguez, et al. 2001. System assessment of the Joint Biological Point Detection System. U.S. Army ATEC Report, Alexandria, Virginia.

Fitch, J. P., B. P. Mark, W. Colclasure, M. Coleman, P. E. Coyle, H. H. Hill, N. B. Jackson, et al. 2004. *Review of test and evaluation methodology for biological point detectors*. Washington, D.C.: The National Academies Press.

Holman, C., I. Kuria, N. Dunn, J. Timmerman, S. Colegrove, P. Serguievski, J. Kleimeyer, et al. 2007. Report of the modeling and simulation of the Joint Service Lightweight Standoff Chemical Agent Detector (JSLSCAD). U.S. Army Test and Evaluation publication, March 2007. (Classified at the secret level.)

Holman, C. E., M. Moe, C. T. Russell, C. Jennings, R. Bartholomew, and D. Anderson. 2008. Technical Note: Whole System Live Agent Test (WSLAT) methodology and performance assessment. U.S. Army Test and Evaluation publication, September 2008.

Musgrave, D., N. Dunn, F. Gasiorowski, J. Winters, S. Tackett, and C. Holman. 1997. System evaluation report of the Joint Service Lightweight Integrated Suit Technology I (JSLIST I) Developmental and Operational Tests (DTs and OTs). U.S. Army Test and Evaluation publication, April 1997.

Przybylowicz, E., E. Browell, D. Chase, J. De Haseth, R. Flagan, P. Griffiths, D. Layton, T. Reichardt, and L. Rhomberg. 2003. Testing and evaluation of standoff chemical agent detectors. Washington, D.C.: The National Academies Press.

Shirakawa, K., C. T. Russell, and C. E. Holman. 2008. Estimating performance of a standoff biological detector system agents actual biological warfare agent. MORSS, June 10–12, 2008. New London, Connecticut: U.S. Coast Guard Academy.